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MEASUREMENT OF HYDRAULIC CONDUCTIVITY USING A RADIOACTIVE OR ACTIVATABLE TRACER - AU2007231556

ABSTRACT & PATENT DETAILS

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WO 2007/109860 PCT/AU2007/000405 1 MEASUREMENT OF HYDRAULIC CONDUCTIVITY USING A RADIOACTIVE OR ACTIVATABLE TRACER TECHNICAL FIELD 0001] The present invention relates to the measurement of conductivity of liquids in underground formations. More particularly, the invention relates to a method of determining the distance from a borehole of a volume of liquid in an underground environment of the borehole, to a method of determining hydraulic conductivity of a liquid in an underground environment of a borehole, to a system for determining hydraulic conductivity of a liquid in an underground environment of a borehole, and to an apparatus for determining the distance from a borehole of a volume of liquid in an underground environment of the borehole. [0002] The invention further relates to a bore-logging tool adaptable for use in determining the distance, from a borehole, of a volume of liquid in an underground environment of the borehole. The invention also relates to a tool and a kit adaptable for use in determining hydraulic conductivity. BACKGROUND OF THE INVENTION [0003] One method that is currently used for the measurement of hydraulic conductivity in underground formations involves the pumping of water, under pressure, into the formations surrounding a borehole, and the subsequent measurement of the volume and pressure of water flowing from the borehole. This method is referred to as the "pump testing" method. [0004] The measurement of hydraulic conductivity according to the pump testing method is subject to inherent inaccuracies. These inaccuracies may be ascribed to: a) inaccuracies in the formulae used for calculation of the hydraulic conductivity; b) an imperfect correlation between actual and calculated flow rates as a function of decreasing pressure differential between the inside and the outside of the borehole; and c) inaccuracies originating from approximations and averaging of measured values. [0005] A further disadvantage of this method is that, in existing boreholes lined with casings, there are either no holes through the casing in the zone of interest or, where slots or holes have been provided, they are located only in predetermined regions. Because of the influence of the positions of such holes on the flow of liquids in the borehole and its environment, these and other factors complicate the use of the pump testing method and contribute to its inaccuracy. [0006] Screen intervals in the bore casing range from about 3 m to about 6 m. Even greater screen widths than 6 m are sometimes used. Typically, this means one low spatial resolution value

This page contains all relevant details related to patent number AU2007231556. This patent was filed on 29/03/2007 and has a status of LAPSED. The inventors associated with this patent are:

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The applicant/owner of the patent is registered as Australian Nuclear Science & Technology Organisation. They used the patent attorney firm Spruson & Ferguson to file this.

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PUBLICATIONS

Vol/Iss	Pub. Date	Publication Action	Reason
25/13	31/03/2011	Patent Lapsed	Did not ask for an examination within the prescribed time.
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CLAIMS

CLAIMS: 1. A method of determining the distance, from a reference point, of a tracer emitting radiation comprising a first component emitted at a first known energy level and a second component emitted at a second known energy level, the intensity of a penetrating portion of the first component that penetrates a substance between the tracer and the reference point and the intensity of a penetrating portion of the second component of the radiation that penetrates the substance being a function of the rate of gamma radiation emission of the tracer as well as of the distance of the tracer from the reference point, the method comprising: a) measuring the intensity of the first penetrating portion and the intensity of the second penetrating portion; b) determining the ratio of the intensity of the first penetrating portion to the intensity of the second penetrating portion; and c) determining the distance of the tracer from the reference point. 2. A method as claimed in claim 1 wherein step (c) comprises determining the distance of I, (1) p, 2 -11' the tracer from the reference point using the equation Rt(l) = , wherein: I2t () , 1 , wherein: Rt(1) is the ratio of the integral intensities of the tracer gamma radiation emission at two different energies; 1 is the distance of the volume of liquid containing the radiotracer from the reference point; Io t (1) represents the total (integral) intensity of the tracer at the first energy as a function of the distance from the reference point; I2ot(1) represents the total (integral) intensity of the tracer at the second energy as a function of the distance from the reference point; pa is the attenuation coefficient of the first component of the radiation corresponding to the first the energy; and p2 is the attenuation coefficient of the second component of the radiation corresponding to the second the energy; and further wherein if an activatable tracer is used then the methodWO 2007/109860 PCT/AU2007/000405 -56 further comprises the step of activating the activatable tracer before the step of measuring the intensity of the first penetrating portion and the intensity of the second penetrating portion. 3. A method as claimed in claim 1 further comprising the step of d) mixing the tracer with water throughout a column of water or other liquid in the borehole. 4. A method as claimed in claim 3 further comprising the step of e) applying a known pressure head to the borehole to induce the injection of the tracer into the environment of the borehole. 5. A method as claimed in claim 4 wherein the pressure head in the borehole is maintained o constant at a constant pressure to ensure that the tracer is injected into the borehole environment at a constant rate. 6. A method as claimed in claim 1 wherein the tracer is selected from the group of radioactive or activatable tracers. 7. A method as claimed in claim 6 wherein the radioactive tracer is in the form of a is chemical substance comprising a radioactive element. 8. A method as claimed in claim 7 wherein the radioactive element prepared off site. 9. A method as claimed in claim 7 wherein the radioactive element prepared in situ by a suitable source of radioactivity 10. A method as claimed in claim 9 wherein the source is a neutron radiation source, the radiation being capable of causing elements in the borehole environment to become radioactive. 11. A method as claimed in claim 10 wherein the neutrons could have a penetrating range of approximately 1 mm to 1 m. 12. A method as claimed in claim 6 wherein the tracer is a chemically conservative salt. 13. A method as claimed in claim 12 wherein the chemical salt is selected from the group of NaC1, KCI, MnC1 2 , Na 2 SO 4 , K 2 SO 4 , NaBr, NH4C1 or KBr, or combinations thereof. 14.

A method as claimed in claim 12 wherein the chemical salt is selected from the group of NaC1, KC1, or KBr. 15. A method as claimed in claim 14 wherein the salt is labelled with ^{82}Br. 16. A method as claimed in claim 13 wherein one or more of the elements in the salt is a radioactive isotope.WO 2007/109860 PCT/AU2007/000405 -57 17. A method as claimed in claim 13 wherein one or more of the elements in the salt are able to be activated with incident neutrons to emit gamma radiation. 18. A method as claimed in any one of claims 1 to 17 wherein the tracer is sodium chloride. 19. A method as claimed in any one of claims 1 to 17 wherein the tracer is ^{82}Br. 20. A method as claimed in any one of claims 1 to 17 wherein the tracer is sodium or potassium bromide wherein the bromide is ^{82}Br. 21. A method as claimed in any one of claims 1 to 17 wherein the tracer is water. 22. The tracer distance measured by diminution of the activatable salt as it is displaced by the water injection. The distance of the water tracer from the borehole could be measured by differential gamma radiation attenuation, which may be by diminution of the salt intensity. 23. A method as claimed in claim 6 wherein the radioactive or activatable tracer is a mixture of two or more of the compounds selected from the group consisting of NaC1, KC1, $MnCl_2$, Na_2SO_4, K_2SO_4, NaBr and KBr. 24. A method as claimed in any one of the preceding claims wherein the tracer emits gamma radiation at various energy levels. 25. A method as claimed in any one of the preceding claims wherein the tracer is selected according to factors such as the rock and ground water forming part of the borehole environment. 26. A method as claimed in any one of the preceding claims wherein the tracer is selected so as to avoid chemical reaction of the tracer with the rock in the borehole environment or with a borehole casing. 27. A method as claimed in any one of the preceding claims wherein step (a) comprises measuring the intensity of the first penetrating portion and the intensity of the second penetrating portion using a detector. 28. A method as claimed in claim 27 wherein the detector is from the group of gamma radiation scintillation detectors. 29. A method as claimed in claim 27 wherein the detector is selected from the group of a bismuth germinate (BGO) detector, a lanthanum bromide ($LaBr_3Ce$) detector, or a lanthanum chloride (LaC13Ce) detector, cadmium telluride, cadmium zinc telluride, sodium iodide, or a high purity germanium (HPGe) detector. 30. A method as claimed in a one of the preceding claims further comprising the step of shielding the detector from radiation originating from all directions except a desired measurementWO 2007/109860 PCT/AU2007/000405 -58 direction to determine the distance of the tracer from the reference point in the desired measurement direction. 31. A method as claimed in one of the preceding claims where the measurement of the intensity of the first penetrating portion and the intensity of the second penetrating portion is performed over a period of approximately 0.01 to 5 hours 32. A method as claimed in any one of the preceding claims wherein the method further comprises the step of inserting at least one packer into the borehole to isolate a region of interest. 33. A method as claimed in any one of the preceding claims wherein the resolution of the distance of the tracer from the reference point is approximately 10 cm where the borehole is an uncased borehole without packers to isolate each injection zone. 34. A method as claimed in claim 1 wherein the radiation is selected from the group consisting of gamma radiation and X-rays. 35. A method as claimed in claim 34 wherein the energy level of the radiation is in the range of approximately 0.1MeV to 10 MeV. 36. A method as claimed in claim 34 wherein the energy level of the radiation is in the range of approximately 1.0 MeV to approximately 5 MeV. 37. A method as claimed in claim 1 wherein the difference between the first and second energy levels is greater than 0.1 MeV. 38. A method of determining the distance from a borehole of a tracer in an underground environment of the borehole, wherein the tracer emits radiation comprising a first component emitted at a first known energy level and a second component emitted at a second known energy level, the intensity of a penetrating portion of the first component that penetrates the environment and the intensity of a penetrating portion of the second component of the gamma radiation that penetrates the environment being a function of the rate of gamma radiation emission of the tracer as well as of the distance of the tracer from the borehole, the method comprising the steps of: a) measuring the intensity of the penetrating portion of the first energy component of the tracer; b) measuring the intensity of the penetrating portion of the second energy component of the tracer; c) determining the ratio of the intensity of the first energy component to the intensity of the second energy component;WO 2007/109860 PCT/AU2007/000405 -59 d) determining the distance of the tracer from the borehole. 39. A method as claimed in claim 38 wherein the tracer is a radioactive tracer. 40. A method as claimed in claim 38 wherein the tracer is an activatable tracer. 41. A method as claimed in claim 40 wherein the step (a) comprises the steps of: al) activating the activatable tracer; and a2) measuring the intensity of the penetrating portion of the first and second energy components of the activatable tracer. 42. A method as claimed in any one of claims 38 to 41 wherein the tracer emits gamma radiation. 43. A method of determining the volume of a tracer plume of a fluid moving in an environment, comprising the steps of a) introducing into the environment a tracer emitting radiation comprising at least two radioactive components emitted at a first known energy level and at a second known energy level; b) after the elapse of a period of time, measuring the intensity of the first penetrating portion and the intensity of the second penetrating portion; c) determining the ratio of the me